Neutron monitoring

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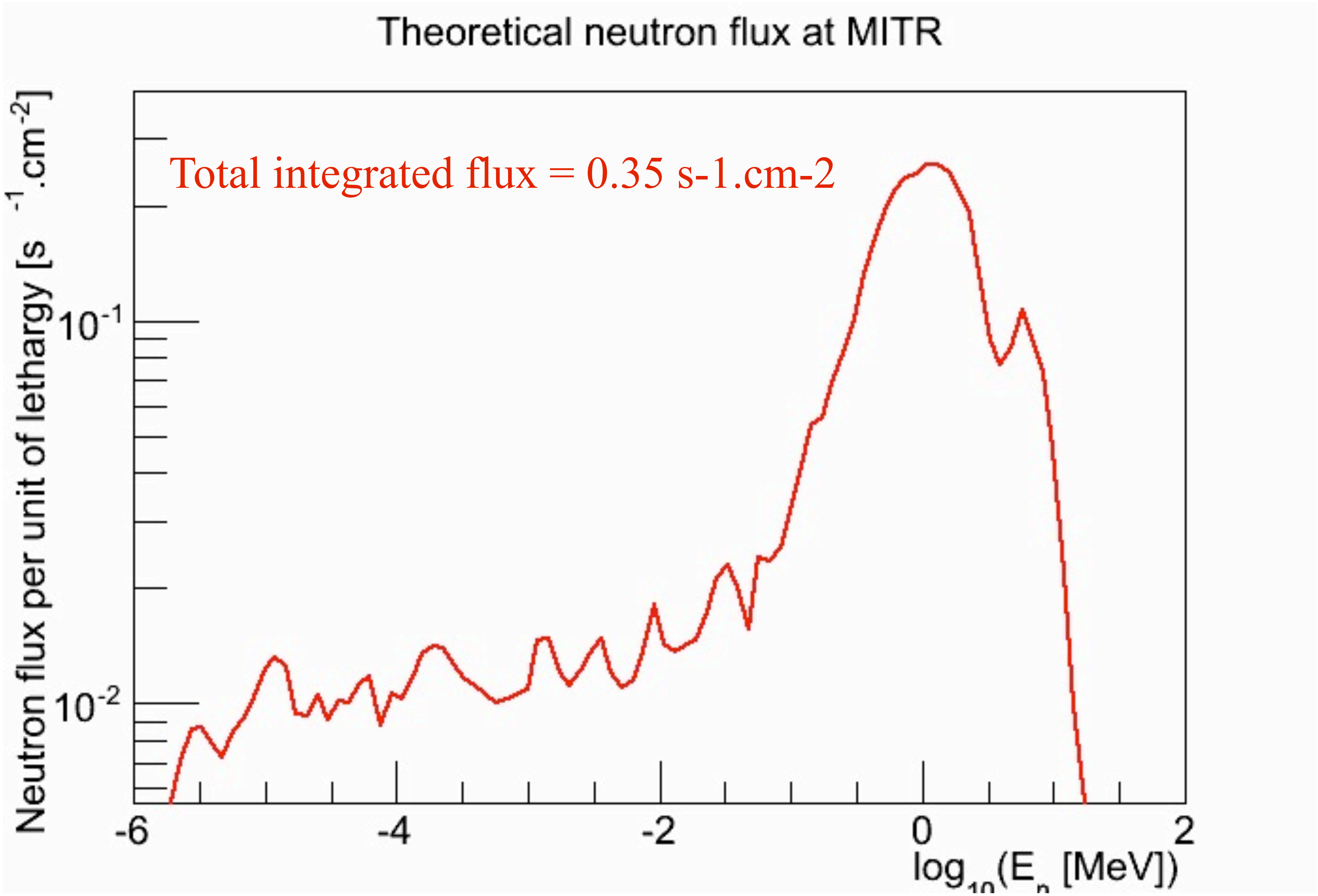
Neutron monitoring



Need to measure neutron flux over 7 orders of magnitude with high precision to predict the number of neutron induced events in the Ricochet experiment

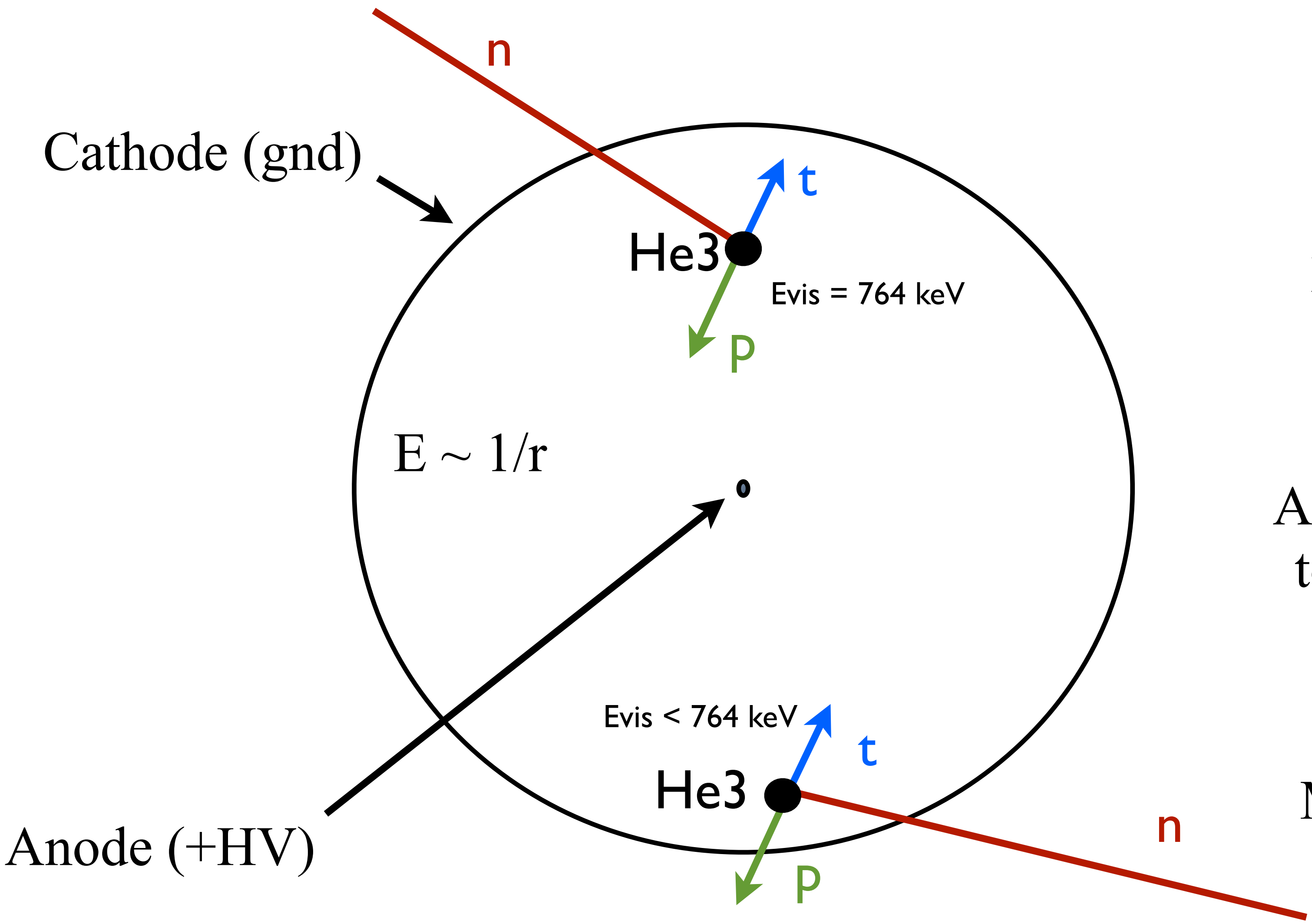
Neutron monitoring

Use of He3 Neutron Capture Detector (NCD) based on the following process:

$$\mathrm{n} + {}^3\mathrm{He} \rightarrow \mathrm{p} + \mathrm{t} \quad (\mathrm{Q} = 764\ \mathrm{keV})$$

proton: 573 keV
triton: 191 keV

- **Cylinder shape:** 200 cm long, 5.08 cm diameter => active volume ~ 4000 cm3
- **Gaseous TPC:** 85% 3He + 15% CF4 @ 2.53 bar



p and t release most of their energy by ionization

↓

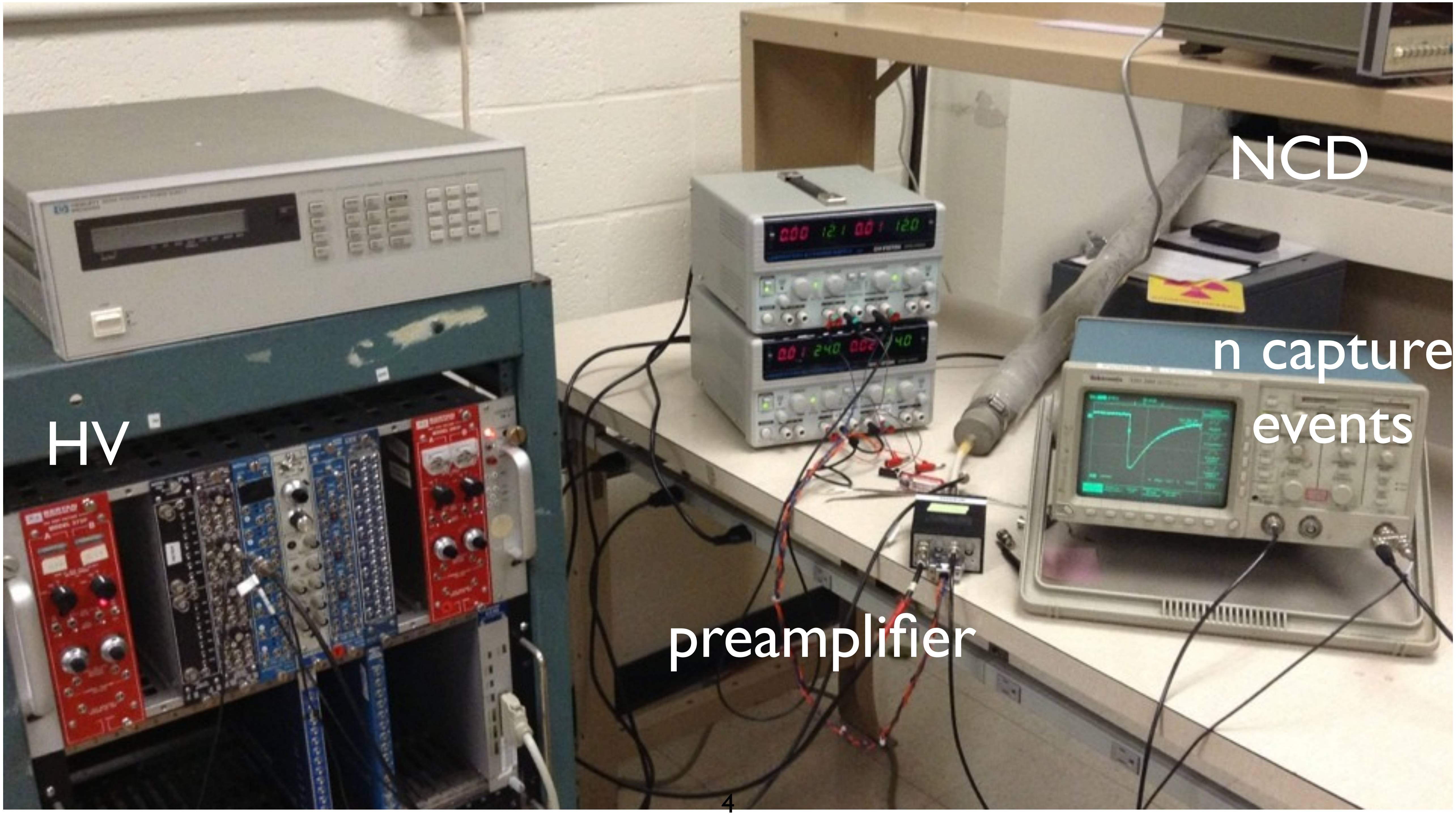
Amplification of the signal due to avalanche process near the anode wire

↓

Measurement of the collected charges proportional to the event energy

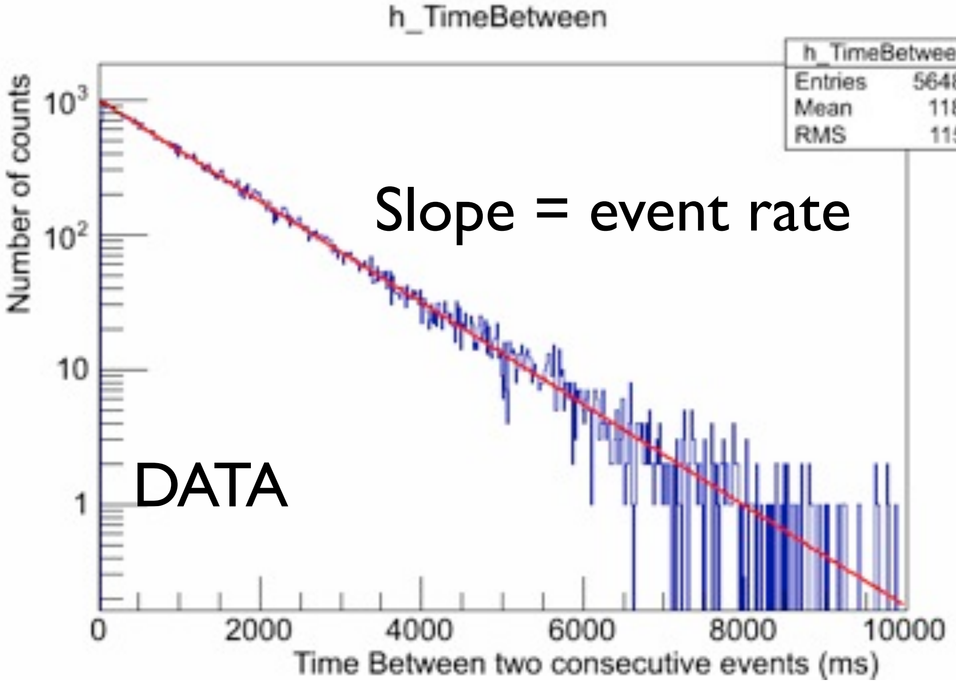
Neutron monitoring

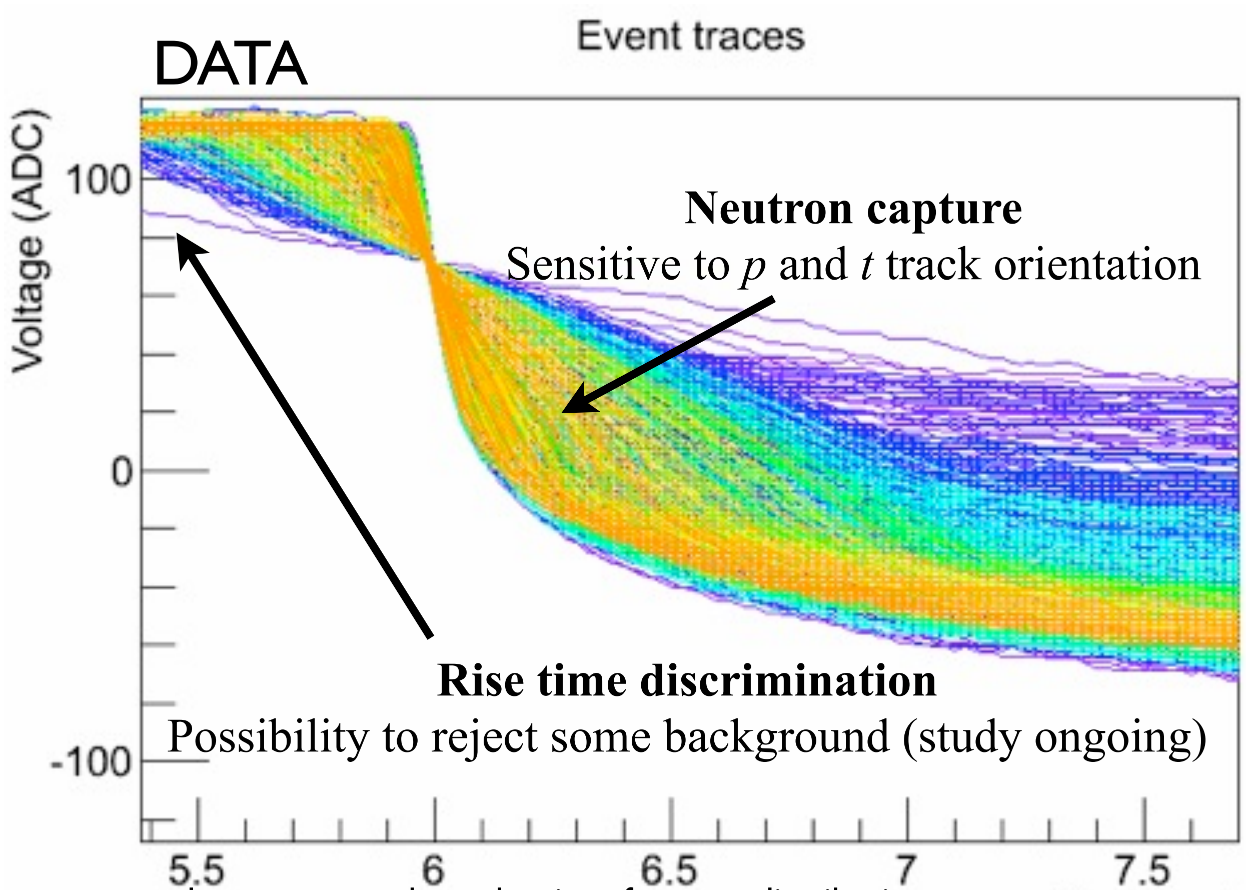
Detector



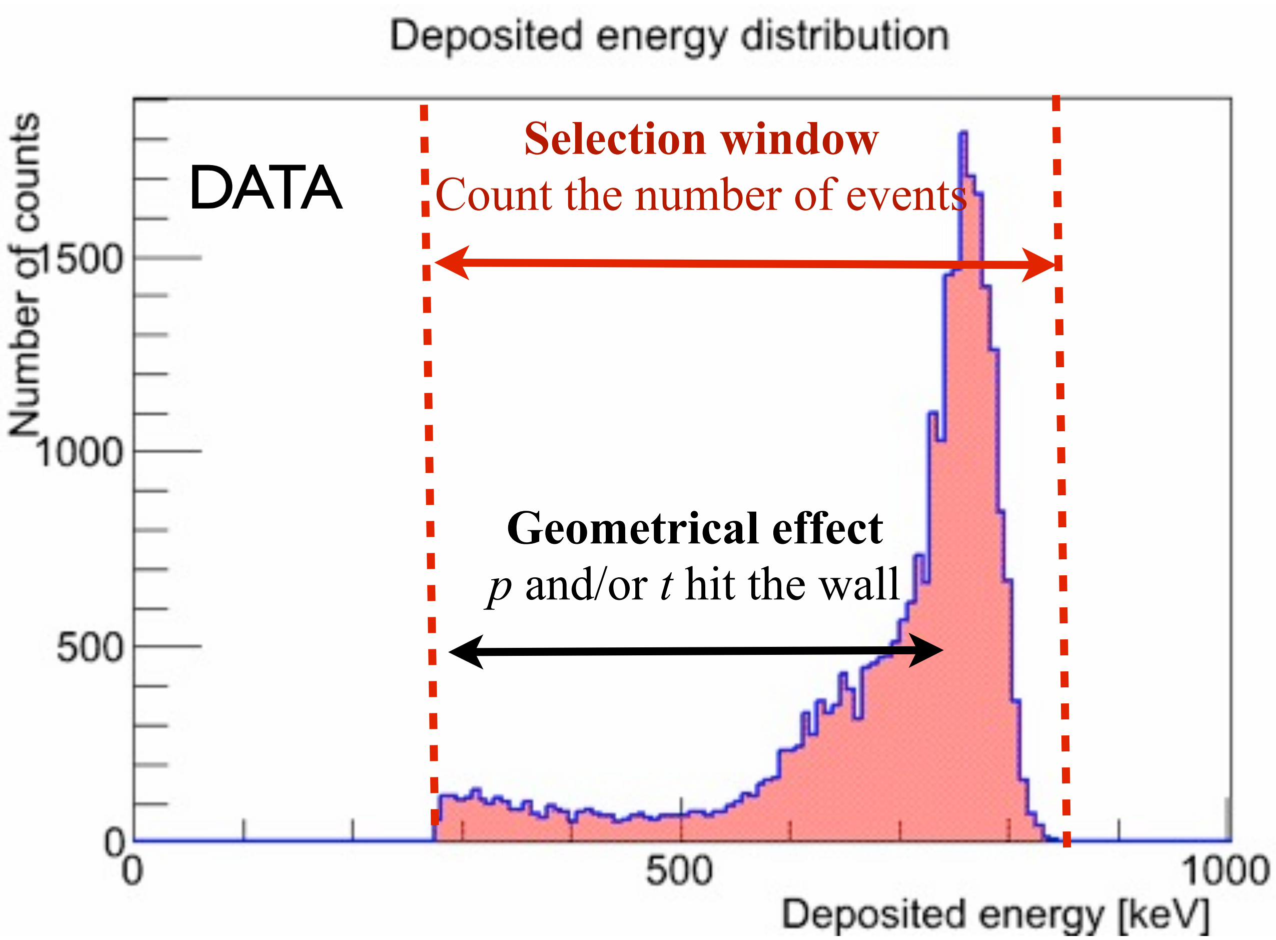
Neutron monitoring

- **Charge readout:** charge preamplifier Canberra (rise time: 75 ns and fall time: 50 us)
- **ADC 8 bits:** NI USB-5132 @ 50 MHz
- **DAQ software:** Labview
- **Optimal HV:** 1.95 kV
- **Energy resolution @ 764 keV**: 3.3%



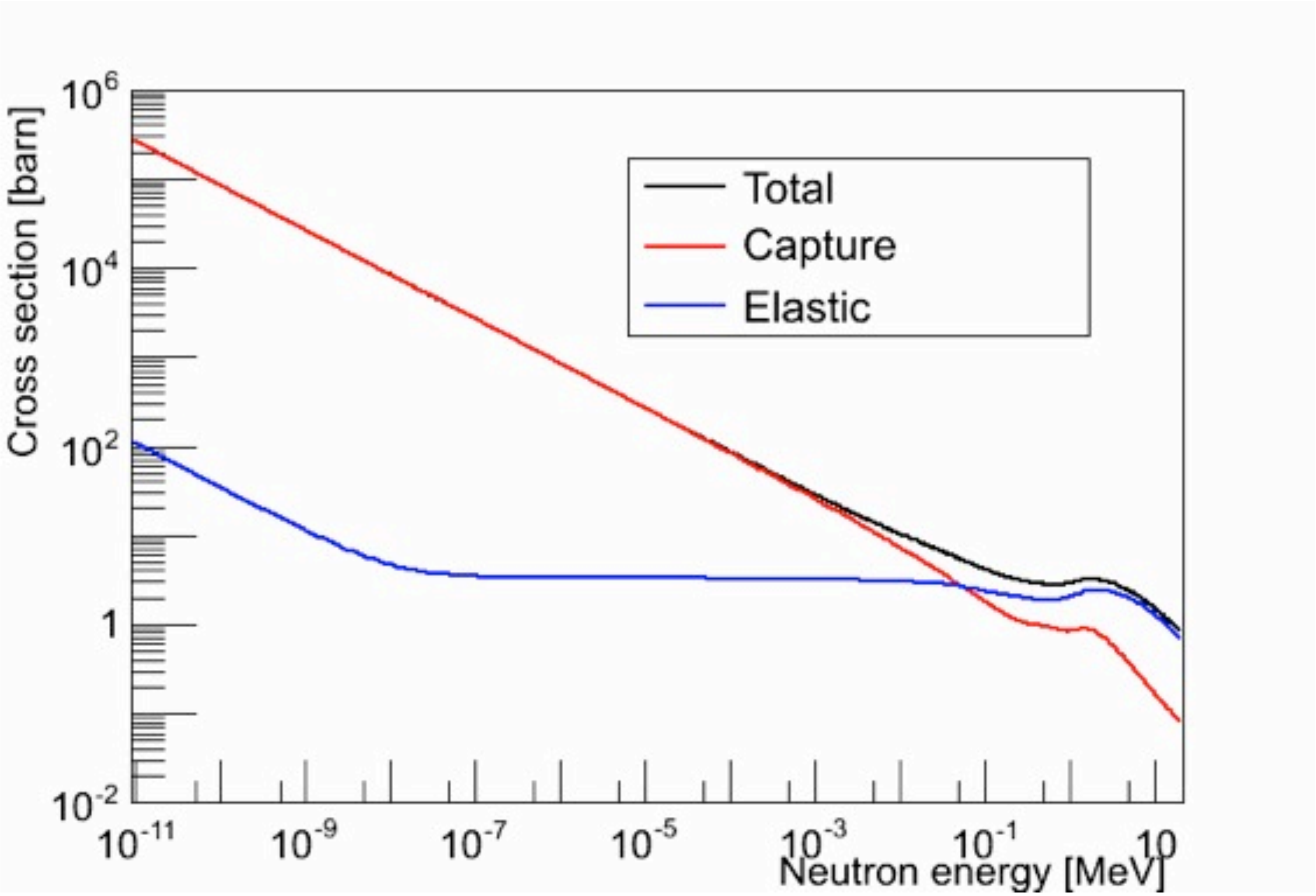


color corresponds to density of energy distribution

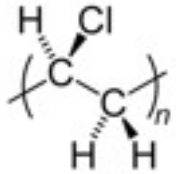


Neutron monitoring

A bonner sphere approach



PVC

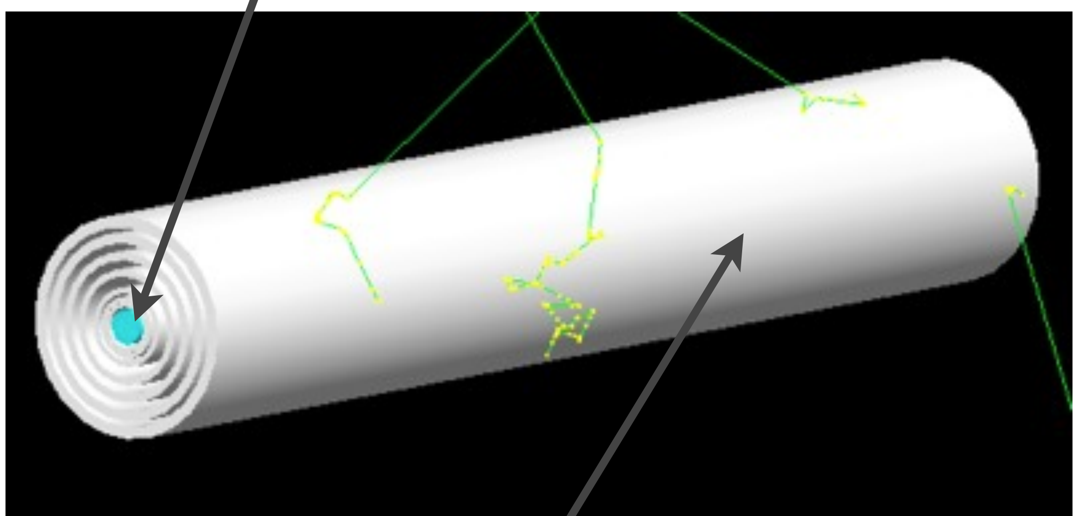


- NCD are mostly sensitive to thermal neutrons (cross section ~ 10^4 barns)
- Use layers of PVC to «slow down» neutrons, due to multiple collisions with hydrogen (mostly), and to be able to measure neutron flux up to MeVs and to recover the energy dependence of the neutron flux!

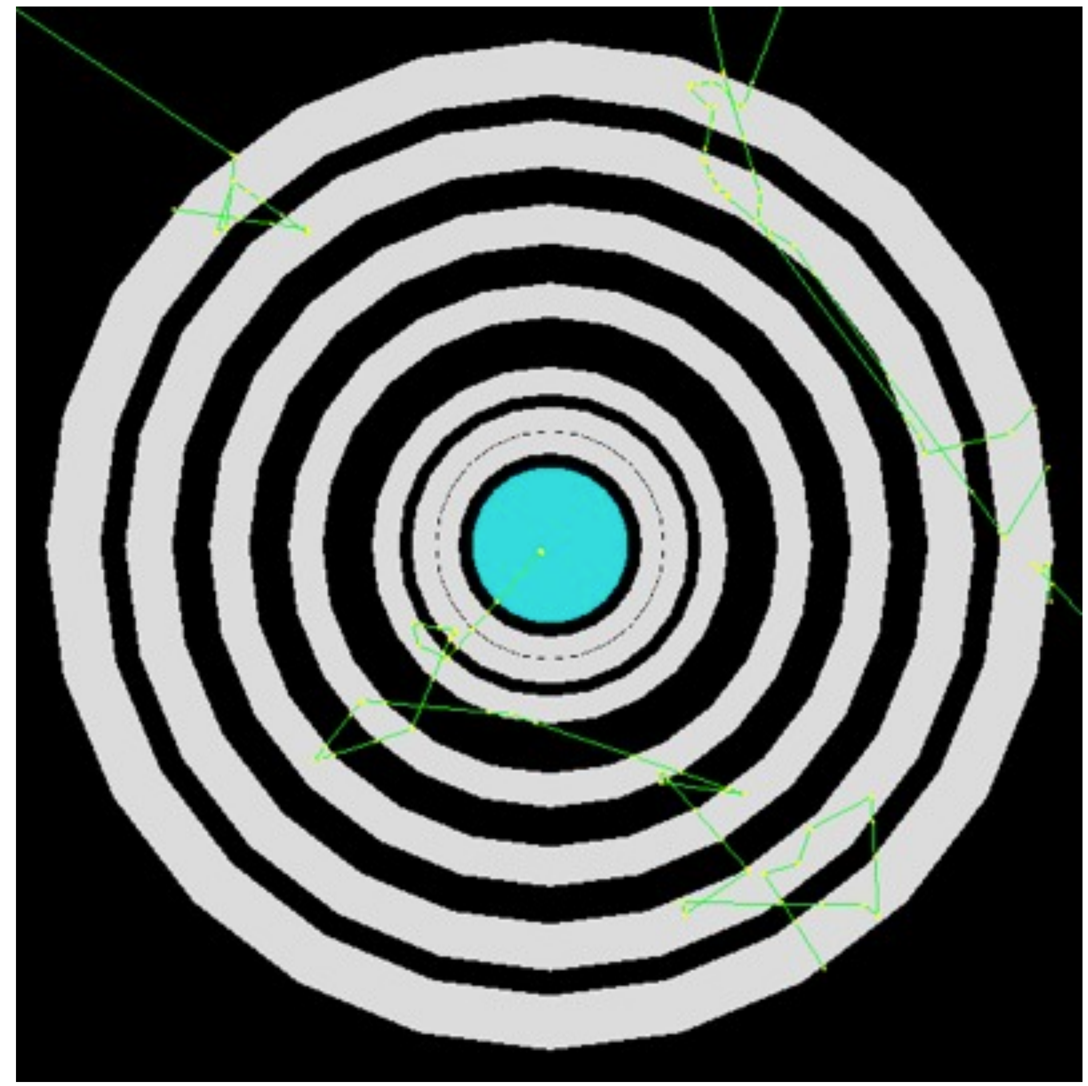
Neutron monitoring

Geant4 simulation of detector

NCD



PVC pipes



Proposed Layers [SI]	inner radius [cm]	outer radius [cm]	nominal thickness [cm]	total thickness of PVC [cm]
2-1/2” (sch. 80)	2.95	3.65	0.70	0.70
3” (sch. 80)	3.68	4.45	0.76	1.46
4” (sch. 80)	4.86	5.72	0.86	2.32
6” (sch. 80)	7.32	8.41	1.10	3.42
8” (sch. 80)	9.68	10.95	1.27	4.69
10” (sch. 80)	12.15	13.65	1.51	6.19
12” (sch. 80)	14.45	16.19	1.74	7.94

Neutron monitoring

Geant4 simulation of detector

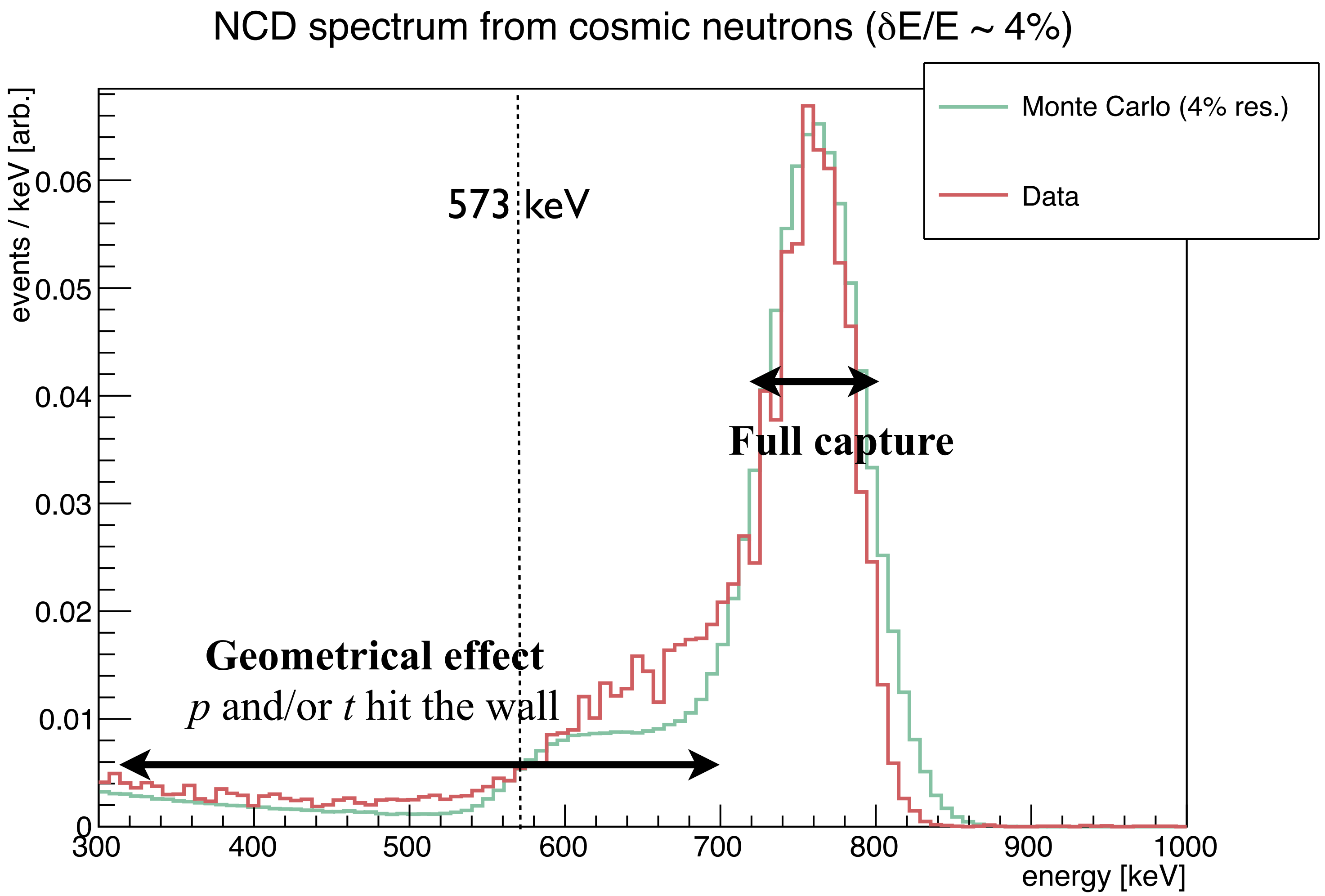
Includes realistic NCD geometry and PVC layers

Tracks physics from neutron injection to p+t production (QGSP_BERT_HP)

Allow us to compute fraction of incident neutrons that capture on 3He, main ingredient of the “transfer function”

Current simulation qualitatively reproduces observed energy spectrum from cosmic neutrons

Quantitative validation of simulation with AmBe source and refined cosmic neutron spectrum underway



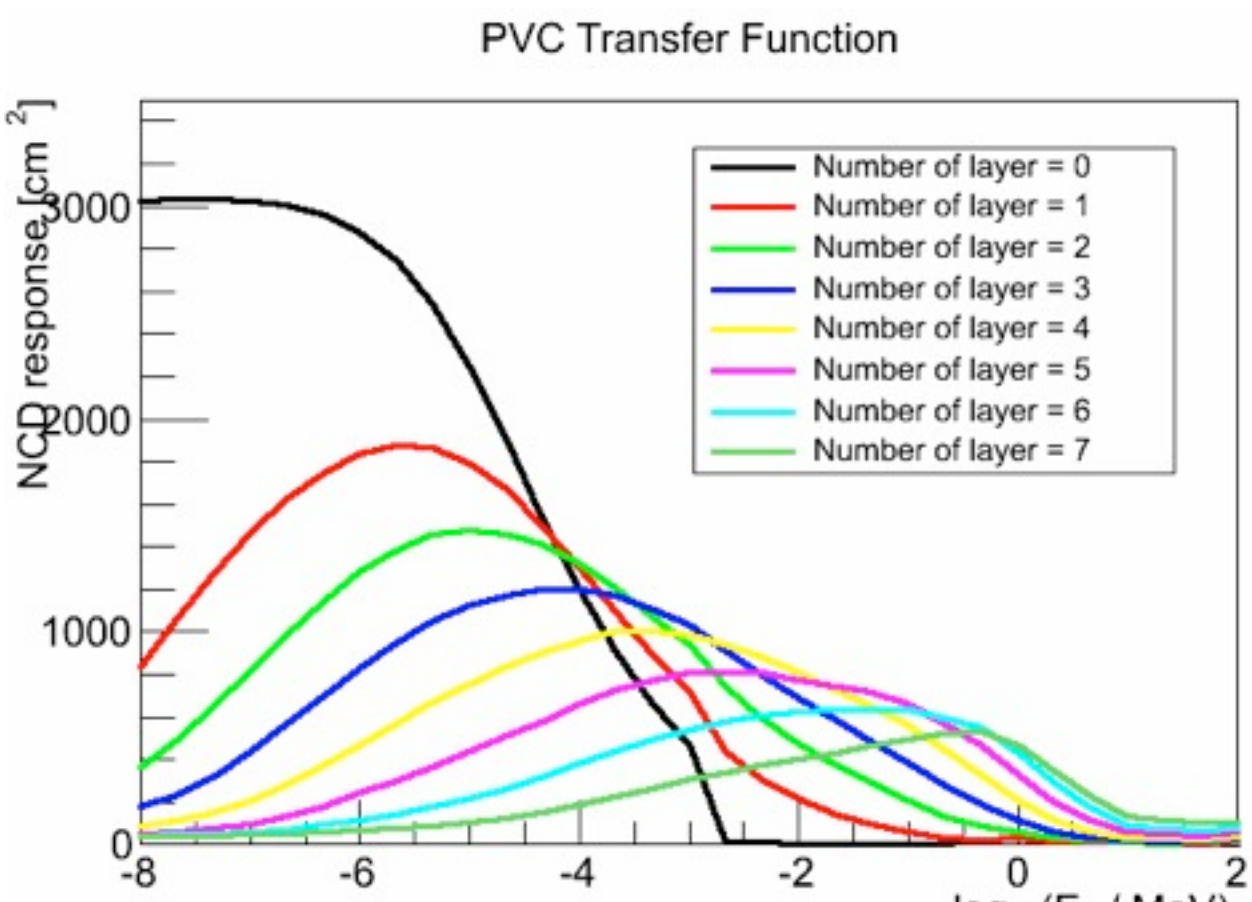
General good agreement but some discrepancies:

- Need to double check with SRIM for the *p* and *t* ranges (shape of geometrical effect)
- Study for possible recombinaison and/or attachment
- Simulation of the whole detector response
- ...

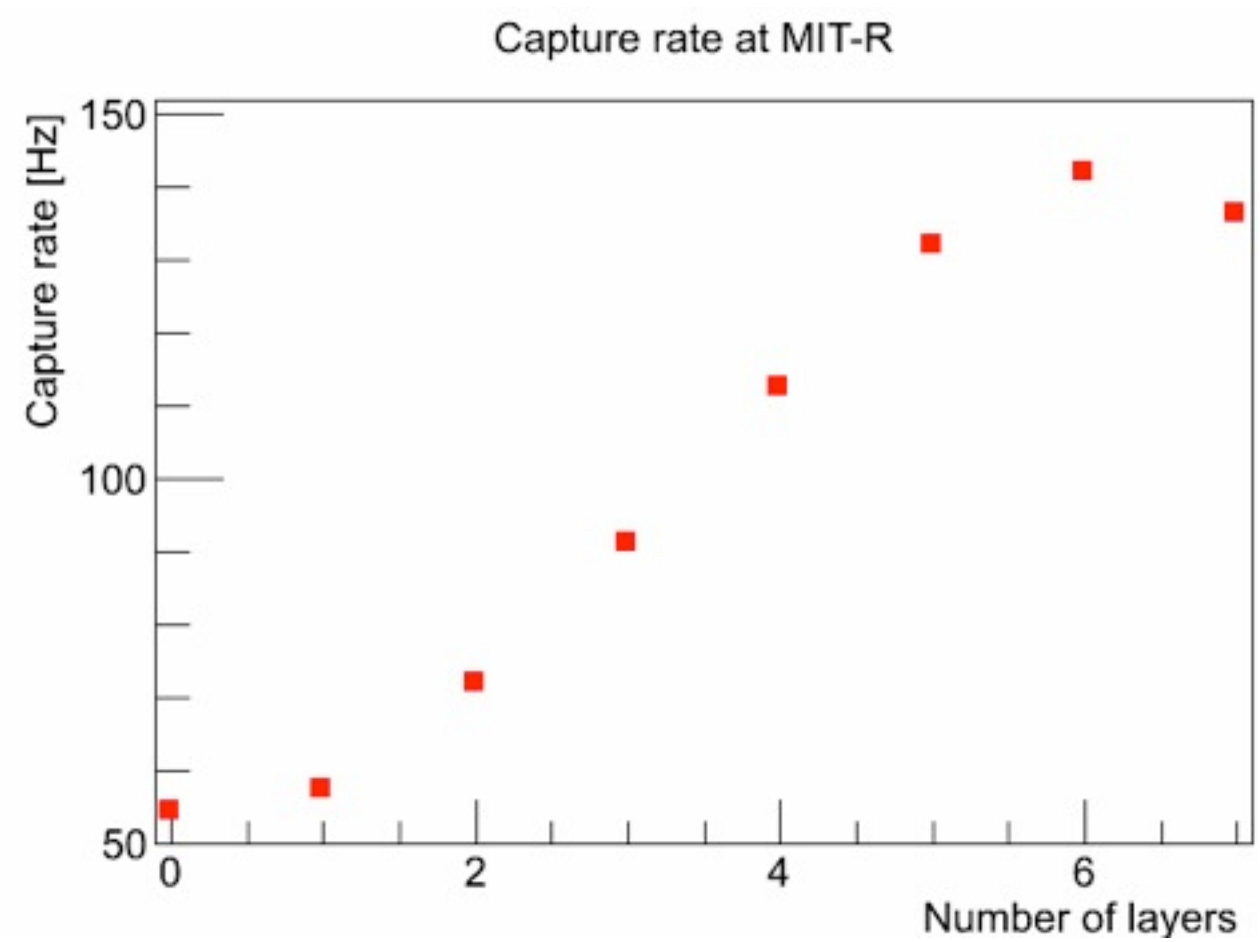
Studies ongoing...

Neutron monitoring

A bonner sphere approach



Taking into account between 200 keV and 765 keV



- We are now sensitive to neutrons up to *0*(10) MeVs!

- As each layer has a sensitivity to a given range of neutron energy, possibility to recover the neutron flux from thermal to fast neutrons.

Neutron monitoring

Recovering the neutron flux from NCD rate measurements: A likelihood approach

Definition of the likelihood function:

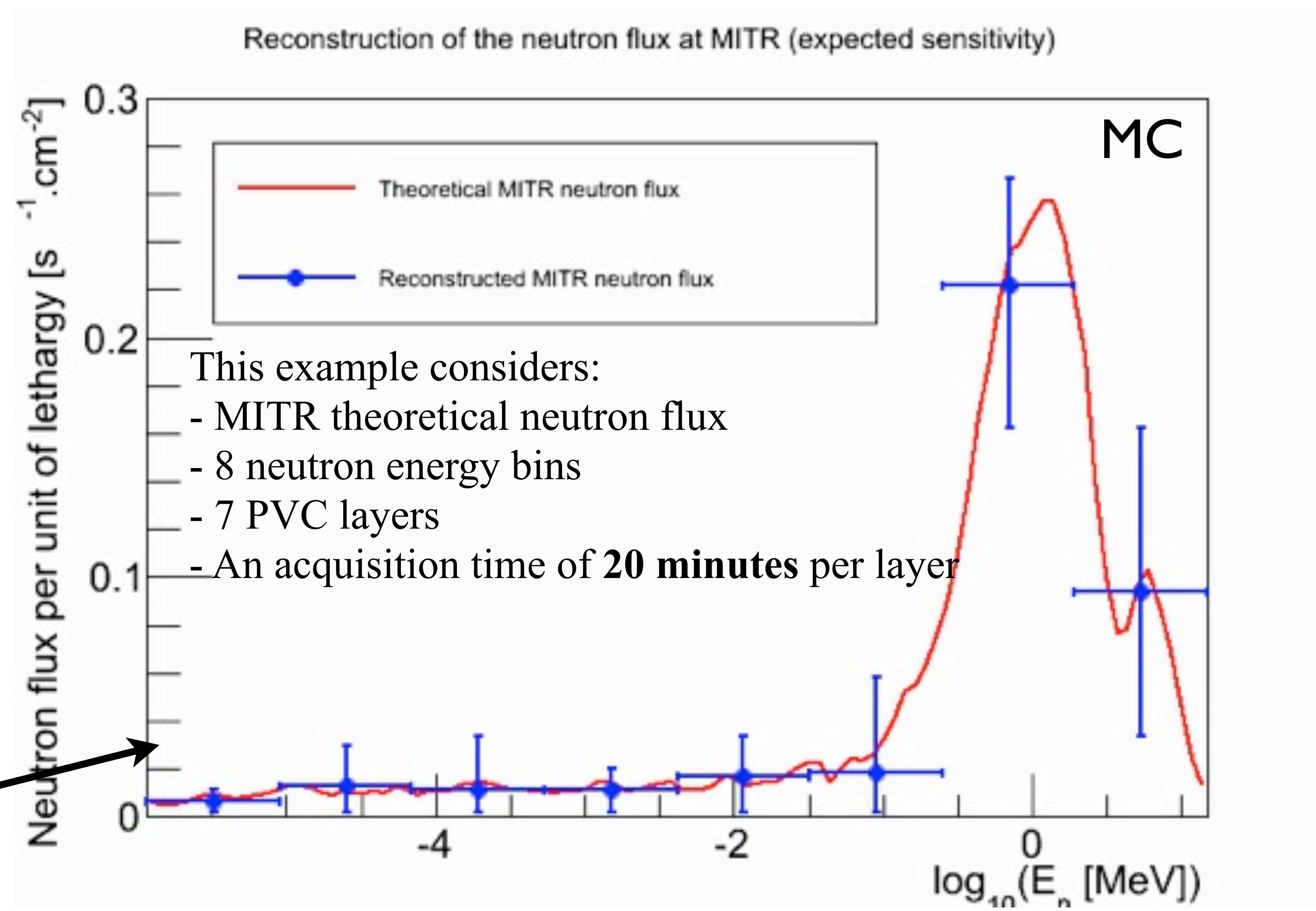
$$\mathscr{L}[\vec{\phi}(\tilde{E})] = \exp\left[- \sum_{j=1}^{N_{\text{layers}}} \frac{\{R_j^{\text{th}}[\vec{\phi}(\tilde{E})] - R_j^{\text{obs}}\}^2}{2\sigma^2_{R_j^{\text{obs}}}} \right]$$

Where the theoretical rates are computed such as:

$$R_j^{\text{th}}[\vec{\phi}(\tilde{E})] = \sum_{i=1}^{N_{\text{bin}}} \int_{\tilde{E}_i}^{\tilde{E}_{i+1}} \phi_i(\tilde{E}) \times T_j(\tilde{E}) \, d\tilde{E}$$

Where $T(E)$ are the transfer functions computed from Geant4

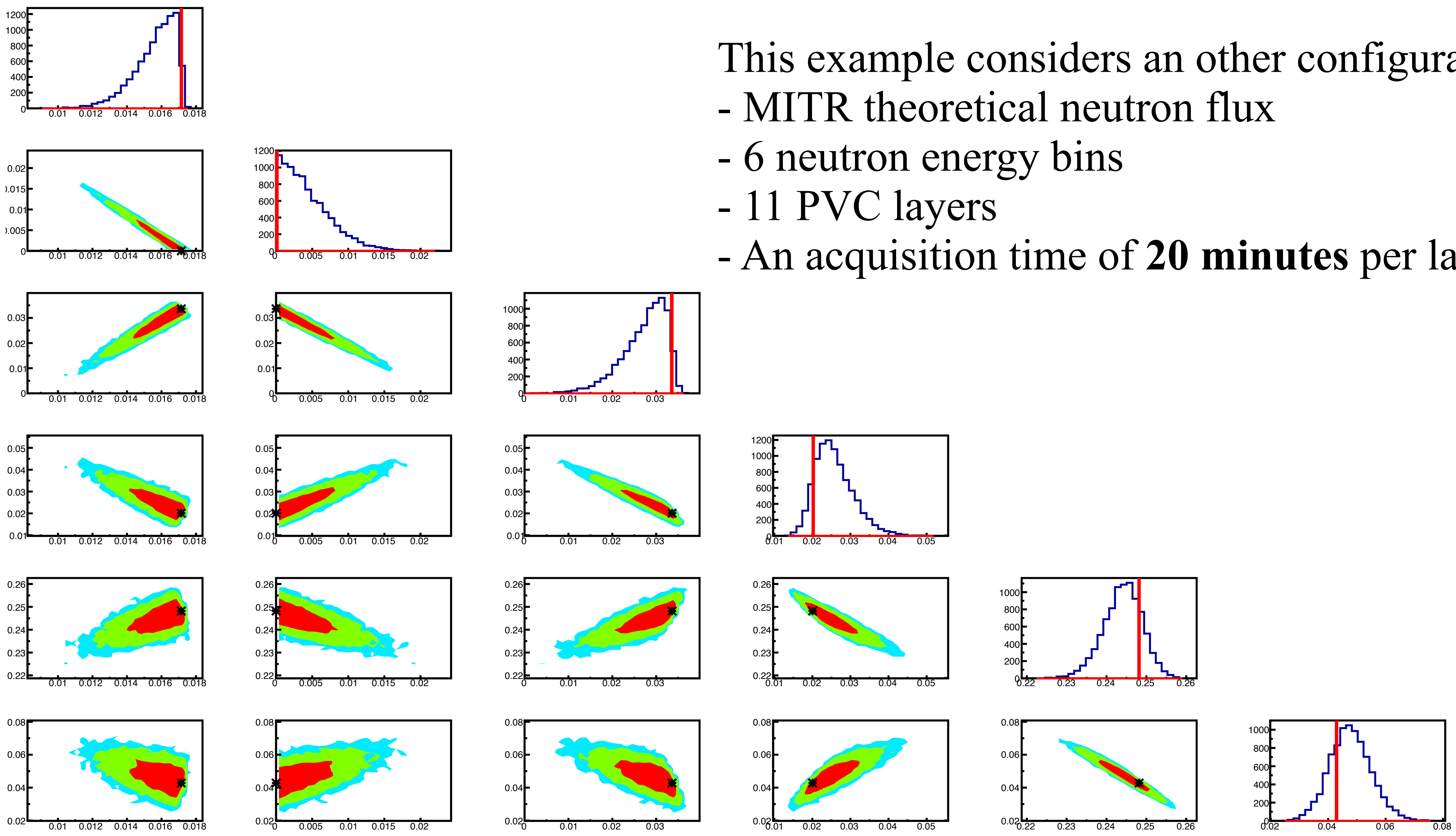
Expected neutron flux reconstruction sensitivity using maximum likelihood distribution



Reconstructed total flux = 0.35 ± 0.02 neutron /s/cm2 (~5% uncertainty)

Neutron monitoring

Estimation of the error propagation using an MCMC sampling



This example considers an other configuration:
- MITR theoretical neutron flux
- 6 neutron energy bins
- 11 PVC layers
- An acquisition time of **20 minutes** per layer

Will allow us to compute the probability density distribution of neutron induced events in Ricochet

Neutron monitoring

Next things to do:

- Build transfer functions from incident neutron energy to NR probability in the Ricochet experiment

- Compare Geant4 and SRIM and simulate the whole detector response

- Construction of the PVC layers (we will get them in a couple of weeks)

- Measure the atmospheric neutron flux and compare it to CRY simulation

- Measure the AmBe neutron flux for cross validation

- Start taking data for the characterization of the MIT Reactor